CHAPTER 1 Motion in a Straight Line

PROGRAM RESOURCES
Physics 11 ExamView® Test Bank
Physics 11 Online Teaching Centre
Physics 11 website
www.nelson.com/onseniorscience/physics11u

TEACHING NOTES
• Have students examine the Chapter Opener photograph. Ask, What advantage do you think this car’s shape provides? (It reduces the effect of air on its motion.)
• Ask students to relate the solar-powered car in the photograph to the key question: What effects do moving objects have on society and the environment? (Sample answer: A solar-powered car does not produce the harmful greenhouse gas emissions that a gas-powered vehicle does.)
• Point out the flat design of the University of Waterloo’s solar vehicle. Ask, Why was this design useful for both the environment and for the motion of the car? (The car’s body mostly consists of a flat solar panel which allows for maximum exposure to the Sun’s rays. The aerodynamic design reduces air resistance.)
• Have students complete the Starting Points questions. Save their answers so that students can review and evaluate them after they have studied the chapter.
• Have students complete Mini Investigation: The Effect of Gravity on the Motion of Objects.

MINI INVESTIGATION: THE EFFECT OF GRAVITY ON THE MOTION OF OBJECTS
Skills: Predicting, Performing, Observing, Analyzing
Purpose: Students will investigate how mass and shape change the effect of gravity on the motion of objects falling through the air.
Equipment and Materials (per group): 2 spherical objects of different mass; 1 sheet of paper
Student Safety: Caution students to drop the spheres away from other students and to pick them up immediately after dropping them.

DIFFERENTIATED INSTRUCTION
• To help verbal, visual, and interpersonal learners understand the results of the Mini Investigation, encourage groups to work together to create illustrations and written descriptions to record their observations.
• You may want to have students who are interested in computers set up a class blog, wiki, or website for posting reports, lab results, presentations, images, videos, links, and other forms of information.

ENGLISH LANGUAGE LEARNERS
• Emphasize to English language learners that many of the terms introduced in the chapter have different meanings when used in other contexts. As students encounter new terms, have them write them with their meanings in a notebook. Encourage students to include notes in their native language to clarify any confusing points.

ENGAGE THE LEARNER
CHAPTER INTRODUCTION
• To preview the major ideas that will be explored in the chapter, review the Key Concepts. Ask a student volunteer to read each Key Concept aloud before it is discussed. Ask prompting questions to assess students’ prior knowledge and to engage students in the topics.
Examples are given:
1. If the circular path around a pond is 2 km long and you walk around it twice, ending at your starting point, what is the total distance you have walked? (4 km)
2. How would you describe the motion of a car? (It starts, stops, accelerates, slows, and turns.)
3. When you trying to hit a baseball, you must judge two pieces of information. What are they? (When the ball will cross the plate, and where it will be located.)
4. If you walk 3 m down a straight hall and then turn around and walk 2 m back, how far are you from your starting point? (1 m)
5. How are graphs helpful when studying science? (Graphs help us visualize concepts and quantities related to the science lesson.)
6. When a car is driving down the highway, is it possible for it to maintain the same speed at all times? (The car may have to speed up and slow down for traffic, but if the road is clear, you can use cruise control to maintain a constant speed.)
7. What do you know about gravity? (It causes objects to be pulled toward Earth.) Is the pull of gravity the same everywhere? (No, the force of gravity is less on the Moon.)
8. What are some reasons that speed is such an important factor in car safety? (Sample answers: Higher speeds make stopping more difficult. More damage results if a car crashes at a higher speed.)

• Have students complete the Starting Points questions. Save their answers so that students can review and evaluate them after they have studied the chapter.
• Have students complete Mini Investigation: The Effect of Gravity on the Motion of Objects.
1.1 Distance, Position, and Displacement

OVERALL EXPECTATIONS: A1; A2; B2; B3

SPECIFIC EXPECTATIONS
Scientific Investigation Skills: A1.8; A1.12; A1.13
Career Exploration: A2.1
Developing Skills of Investigation and Communication: B2.1; B2.5
Understanding Basic Concepts: B3.2

The full Overall and Specific Expectations are listed on pages 3-5.

VOCABULARY
• kinematics
• motion
• distance
• direction
• scalar
• vector
• position
• displacement
• vector scale diagram
• directed line segment

ASSESSMENT RESOURCES
Assessment Rubric 1: Knowledge and Understanding
Assessment Rubric 2: Thinking and Investigation
Assessment Summary 1: Knowledge and Understanding
Assessment Summary 2: Thinking and Investigation

PROGRAM RESOURCES
Skills Handbook A6 Math Skills
Physics 11 ExamView® Test Bank
Physics 11 Online Teaching Centre
Physics 11 website
www.nelson.com/onseniorscience/physics11u

RELATED RESOURCES

SCIENCE BACKGROUND
• If a net force is acting on the object, then the object is accelerating according to Newton’s second law: \( a = \frac{F_{net}}{m} \), where \( a \) is the object’s acceleration and \( m \) is the mass of the object. If no force is acting on the object, or if the forces acting on the object are balanced (meaning there is no net force), then the object is not accelerating. If it is at rest, it will remain at rest. If it is moving, it will continue to move at the same velocity. Neither its speed nor its direction will change.
• In everyday language, words such as “position,” “distance,” and “acceleration” have different meanings from their physics meanings. In physics, very precise definitions are used for these motion words. For example, the position of an object in everyday language might be described as “in the classroom” or “next to the chair.” However, in physics, a position must include a distance and a direction from a reference point. The word “distance” in everyday language may mean either the length of a path directly between two points or the length along a path travelled by an object. In physics, however, a distance is only defined along the actual path of an object. In typical language, a moving object that is going fast may be described as accelerating. In physics, an object is only accelerating if its speed is increasing or decreasing, and/or if the object is changing direction.

TEACHING NOTES
ENGAGE
• Have two students walk from one point to another along different paths in the classroom. Ask each student, What is your distance from the starting point? Students’ answers will depend on their definition of distance. Explain that the word “distance” has a different meaning in physics. In everyday life, people may use “distance” to mean the direct path between two points. In physics, distance is the entire path length.

EXPLORE AND EXPLAIN
• Direct students’ attention to Figure 1. Say, Name some properties of motion for the girl in Figure 1. (Possible answers: distance, height, speed, direction)
• Direct students’ attention to Figure 2. Ask, Why is it important to define a starting point when you describe motion? (Distance and direction are different for different starting points.) How would your instructions be different if you were telling a friend how to get to school from your house than from the library? (From the library, you would say to go 700 m west. From your home, you would say to go 500 m east.) Why is including the direction important? (Your friend might otherwise walk in the wrong direction.)
• Ask, Why is distance a scalar quantity? (It does not include a direction.) What are some other scalar and
vector quantities? (Sample answers: Temperature, density, and mass are scalar quantities. Force and acceleration are vector quantities.)

- Point out the definitions of position and displacement in the margin. Ask, Why do the variables for these quantities have an arrow above them? (The arrow indicates that they are vector quantities.) Explain to students that when they see a position or displacement variable without an arrow, it refers to the magnitude of the quantities.
- Designate a spot in the classroom as the origin. Then have students write vector equations on the board for the positions of other spots that you choose. Or have them write vector equations for displacements between two points relative to the origin.
- Draw students’ attention to Tutorial 1: Calculating Displacement for Motion in a Straight Line on page 10 of the Student Book.
- Work through Sample Problems 1 and 2 with the class. Point out that the motion in Sample Problem 1 starts at the origin, whereas the motion in Sample Problem 2 starts at a position other than the origin. Ask, In what case is the position the same as the displacement? (when the motion starts at the origin and is along a straight path)
- Work through Sample Problem 3. Ask, Why is vector subtraction used in Sample Problem 2, but vector addition is used in Sample Problem 3? (You use vector subtraction when the motion is in different directions.)
- Work through Sample Problem 4. An alternative way to explain Sample Problems 2 and 4 is to say that you choose one direction as positive and any displacement opposite that is subtracted.
- Allow class time for students to work with a partner to solve the Practice Problems. Suggest that students draw diagrams to keep track of directions.
- Before students read “Vector Scale Diagrams”, make sure they understand what the phrase “drawn to scale” means. Provide simple examples. For example, write: “scale 1 cm : 1 km” on the board. Then drawn a 5 cm line segment, and explain that it represents 5 km.
- Help students analyze Figure 5. Point out the directional arrow and the scale description. Explain that the top vector shows the total displacement only if the scale is correctly applied.
- Draw students’ attention to Tutorial 2: Determining Total Displacement for Two Motions in Opposite Directions Using Vector Scale Diagrams.
- Work through Sample Problem 1 with the class. Explain that drawing the vectors tip-to-tail is slightly changed if the initial vectors are in opposite directions. The tip of the second vector is drawn just to the side of the tail of the first vector. The total displacement vector is then drawn from the tail of the second vector to a point alongside the tip of the first.

EXTEND AND ASSESS

- Provide students with maps of the school on which you have marked various points. Have students work in small groups to describe the position of each point. Then have them identify the distances between the points and the displacements if they travelled along different routes between the points.
- Direct pairs of students to write their own one-dimensional vector motion problems and draw diagrams to show the results.
- Have students complete the Questions on page 13 of the Student Book.

DIFFERENTIATED INSTRUCTION

- Visual, kinesthetic and other students will benefit from creating illustrations for the various terms related to kinematics in this section, such as the relationship between motion, distance, and direction. Have auditory learners discuss the relationship with their peers. Kinesthetic learners could act out the relationships.

ENGLISH LANGUAGE LEARNERS

- When using algebraic equations to solve problems, have students write the equations in word form rather than symbols, to reinforce the connection between the equations and the text.

1.2 Speed and Velocity

OVERALL EXPECTATIONS: A1; B1; B2; B3

SPECIFIC EXPECTATIONS

Scientific Investigation Skills: A1.1; A1.2; A1.3; A1.5; A1.6;
Relating Science to Technology, Society, and the Environment: B1.1; B1.2
Developing Skills of Investigation and Communication: B2.1; B2.2; B2.4
Understanding Basic Concepts: B3.1; B3.2

The full Overall and Specific Expectations are listed on pages 3–5.

VOCABULARY

- average speed
- average velocity
- position-time graph
- slope
- rise
- run
- motion with uniform or constant velocity
- motion with non-uniform velocity (accelerated motion)

**SKILLS**
Performing Communicating
Observing Identifying Alternatives
Researching Defending a Decision
Analyzing

**EQUIPMENT AND MATERIALS**
per group:
- motor sensor
- computer or computer interface
- graph paper
- pencil

**ASSESSMENT RESOURCES**
Assessment Rubric 2: Thinking and Investigation
Assessment Rubric 4: Application
Assessment Summary 2: Thinking and Investigation
Assessment Summary 4: Application

**PROGRAM RESOURCES**
Skills Handbook A2 Scientific Inquiry
*Physics 11 ExamView® Test Bank*
*Physics 11 Online Teaching Centre*
Physics 11 website
  www.nelson.com/onseniorscience/physics11u

**RELATED RESOURCES**

**EVIDENCE OF LEARNING**
Look for evidence that students can
- distinguish between average speed and average velocity
- determine the velocity of an object from the slope of a position-time graph
- identify the conditions necessary for motion to be uniform
- describe what a position-time graph looks like for objects that are undergoing constant velocity

**SCIENCE BACKGROUND**
- A laser speed device is an updated version of the radar speed devices used by law enforcement officers in the past. Both types of technology work by sending out a signal and detecting the return signal. Radar devices send out radio waves—waves of light with long wavelengths. These waves travel from the radar device to an object and then reflect off the object. When the radar rays reflect back to the device, they are observed to be traveling with a different frequency due to the Doppler shift. The radar device measures this shift in frequency and determines the speed of the vehicle. Laser devices use infrared waves—waves of light with shorter wavelengths. Laser devices work by shooting out many beams of light in an extremely short amount of time. When each of the beams returns to the device, the distance between the car and device is calculated. The device then calculates how the car’s distance from the device changes over the time the rays are released. In this way, the speed of the car can be measured very accurately. Because the wavelength of a laser device is very short, it can be aimed in such a narrow area that it can determine the speed of an individual car.
- Describing the average speed of an object is often more convenient because it usually contains all of the information needed. The distance travelled, the time interval, and the average speed are all related by a simple equation: \( v_{av} = \frac{\Delta d}{\Delta t} \). If you know any two of the three variables, you can easily calculate the third. This is a powerful equation because it allows you to describe the motion of a trip without knowing how the speed might have increased or decreased during the time interval.

**POSSIBLE MISCONCEPTIONS**
**Identify:** Students might think that velocity must be positive.
**Clarify:** Average velocity is the change in displacement divided by the change in time. If the displacement is negative, then the velocity is also negative.
**Ask What They Think Now:** At the end of this discussion, ask, *What is an example of motion involving negative velocity?* (Possible answer: Motion that results in any negative displacement, such as \( \Delta d = -5 \text{ km [E]} \), during a time interval has a negative velocity.)

**TEACHING NOTES**
**ENGAGE**
- Describe or show a photo of cars on a straight stretch of highway. Ask, *How would a car’s speed change if the car traveled a longer distance in the same amount of time?* (Speed would increase.) *How would traveling the same distance in a shorter time affect speed?* (Speed would increase.)

**EXPLORE AND EXPLAIN**
- Point out that the laser speed device in Figure 1 applies the equation for average speed to determine the speed of an approaching car.
- Point out to students that the equation for average speed does not have arrows over the variables. This is not a vector equation. When they apply the equation, they do not need to include directions in their answers.
- Draw students’ attention to *Tutorial 1: Calculating Average Speed* on page 14 of the Student Book.
• Work through the two sample problems with the class. Remind them to use significant digits in writing their answers.

• Sample Problem 1 is a straightforward application of the average speed equation. Sample Problem 2 requires students to rearrange the equation to solve for displacement. Students must also cancel units of seconds to solve for the answer in metres.

• Allow time for students to work through the Practice Problems in class. Notice that Practice Problem 3 is a slightly different application. Some students may need extra assistance in solving for the time interval, Δt.

• Have students complete Research This: Searching for Speeders.

RESEARCH THIS: SEARCHING FOR SPEEDERS
Skills: Researching, Analyzing, Communicating, Identifying Alternatives, Defending a Decision
Purpose: Students will research how laser speed devices are used locally and decide if the use of the devices is justified.
Notes
• Have students work with a partner for their research. Afterwards, provide time for students to conduct a class debate on the issue.
• Explain to students that the use of laser speed devices is a controversial issue. Encourage students to consider various arguments, such as whether they are the best technology available, whether they can be used reliably with minimal training, and whether they should only be used under certain conditions.

• Ask, How is average velocity different from average speed? (Average velocity has a direction associated with it.) Point out to students that they should always look for the arrow above the variable to decide if a quantity is a vector (for average velocity) or a scalar (for average speed).

• Use Figure 2 and Figure 3 to review slope with students. Ask, What points should you use for the displacement? (It does not matter. If the speed is constant, using any two points will give the same slope.) Have students calculate the slope using various points to stress this concept.

• Write the equation for average velocity on the board. Point out the arrows above average velocity and above displacement. Ask, Why is there no arrow above the time interval? (It is a scalar quantity.)

• Draw students’ attention to Tutorial 2: Solving Problems Using the Equation for Average Velocity on page 17 of the Student Book.

• Work through the Sample Problems with the class. Point out that Sample Problem 1 is solved just like an average speed problem except the displacement direction is carried along with the calculation.

• When solving Sample Problem 2, make sure students understand what “ratios equal to one” means. Remind them that multiplying any value by one does not change the value. Similarly, multiplying any value by a ratio equal to one does not change the value. A ratio equal to one is any fraction in which the numerator is equal to the denominator.

• Draw students’ attention to the step in Sample Problem 2 where the two extra digits are carried. Ask students why this is necessary. (Carrying extra digits prevents round-off errors.)

• Allow time for students to solve the Practice Problems in class.

• Discuss the scenes described in Table 1. Ask, Why is it important to show the car in the top photo traveling along a straight road? (Changing direction is changing velocity, and the motion would not be uniform.) Is it possible for the Ferris wheel to travel at a uniform velocity? Explain. (No. The continual change in direction means its velocity is changing.)

• As students study the graphs in Table 2, suggest that they focus on how (or if) the position changes and how (or if) the velocity changes. Have students make flashcards for themselves with a graph on one side and a simple description of the position and velocity on the other side.

• Make sure students pay attention to the placement of the curves in Table 2 compared to the horizontal axis. Explain that although curves below the axis indicate a negative position, this does not mean necessarily that the velocity is negative. It is the slope—not the location of the curve above or below the axis—that indicates whether the velocity is positive or negative.

• Have students complete Mini Investigation: Bodies in Motion.

MINI INVESTIGATION: BODIES IN MOTION
Skills: Performing, Observing, Analyzing
Purpose: Students will use a motion sensor to investigate the relationship between motion and a position-time graph.
Equipment and Materials (per group): motion sensor; computer or computer interface; graph paper; pencil
Notes
• Have students work in small groups for this investigation.
• Make sure students know how to use the motion sensor. Demonstrate how to use the computer interface to generate graphs from their data.
• For Step B, have students experiment with movement toward and away from the motion sensor to see the interesting designs they can produce in their graphs. After they generate letters of the alphabet, ask them to describe places in one or two of the graphs where velocity is increasing, decreasing, or constant.

EXTEND AND ASSESS
• Have interested students research the use of radar devices or laser speed devices to measure the speed of baseball pitches.
• As a challenge for advanced students, have them apply the equation for average speed to two light pulses, using
the speed of light as the average speed, to demonstrate how the technology can determine $\Delta d/\Delta t$ for an approaching car.

- Have students complete Investigation 1.2.1. Applicable teaching notes can be found on page 25 of this resource.
- Have students complete the Questions on page 20 of the Student Book.

**DIFFERENTIATED INSTRUCTION**

- Allow students to choose a format of their choosing for the Research This and Mini Investigation activities. Visual learners might choose to create posters or videos that support their conclusions. Auditory learners might prefer to mediate a class discussion. Kinesthetic learners may enjoy demonstrating the different types of motion during the lesson.

**ENGLISH LANGUAGE LEARNERS**

- Have students practise explaining, either orally or in writing, the relationships expressed in each of the formulas used in this section.

## 1.3 Acceleration

**OVERALL EXPECTATIONS:** A1; B2; B3

**SPECIFIC EXPECTATIONS**

- **Scientific Investigation Skills:** A1.1; A1.5; A1.6; A1.8; A1.11; A1.12; A1.13
- **Developing Skills of Investigation and Communication:** B2.1; B2.2; B2.3; B2.4; B2.6; B2.7
- **Understanding Basic Concepts:** B3.1

*The full Overall and Specific Expectations are listed on pages 3–5.*

**VOCABULARY**

- acceleration
- velocity-time graph
- motion with uniform acceleration
- instantaneous velocity

**SKILLS**

- Predicting
- Analyzing
- Performing
- Communicating
- Observing

**EQUIPMENT AND MATERIALS**

- per group:
  - computer access
  - graphing paper
  - graphing calculator or spreadsheet

**ASSESSMENT RESOURCES**

- Assessment Rubric 2: Thinking and Investigation
- Assessment Rubric 4: Application
- Assessment Summary 2: Thinking and Investigation
- Assessment Summary 4: Application

**PROGRAM RESOURCES**

- BLM 1.3-1 Analyzing a Velocity-Time Graph
- Skills Handbook A2 Scientific Inquiry
- Skills Handbook A6 Math Skills
- *Physics 11 ExamView® Test Bank*
- *Physics 11 Online Teaching Centre*
- Physics 11 website
  - www.nelson.com/onseniorscience/physics11u

**RELATED RESOURCES**


**EVIDENCE OF LEARNING**

Look for evidence that students can

- calculate acceleration from the change in velocity and time interval
- use a velocity-time graph to determine an object’s acceleration and displacement
- determine instantaneous velocity from a position-time graph
- determine average velocity from a velocity-time graph

**SCIENCE BACKGROUND**

- Velocity is the rate at which an object changes position over time. Acceleration is an increase or decrease in this rate of change. In other words, acceleration is the rate at which velocity changes over time.
- The term “acceleration” is commonly misused in everyday life. Often, people use the term “acceleration” when they mean velocity.
- Various terms are used to describe the acceleration of an object whose velocity is changing in the direction opposite the direction of motion. For example, suppose a car’s velocity decreases from 30 m/s [E] to 25 m/s [E] in 1 s. The car’s direction of motion is east, but its acceleration is west. If east is chosen as the positive direction, then the acceleration is $-5$ m/s². An object is said to be decelerating if its acceleration is in the opposite direction to its velocity. Another term that is sometimes used is “negative acceleration,” but this term is ambiguous. If, in the above example, west is chosen as the positive direction, then the acceleration would be positive, even though it is opposite the direction of velocity. It is better to use the term “deceleration” or simply “acceleration.”
TEACHING NOTES

ENGAGE
• Ask students to describe examples of acceleration by an object moving in a straight line. They might mention a car speeding up or slowing down, or a ball that slows down as it rolls across a field. Point out that acceleration can result from either an increase or a decrease in velocity.

EXPLORE AND EXPLAIN
• Draw students’ attention to the free-fall ride in Figure 1. Ask students if they have ever taken one of the rides. Ask, *What happens to the velocity of the riders as they fall?* (The velocity increases at first. It decreases near the end of the ride when the riders come to rest.) Explain that anytime an object’s velocity changes, it is accelerating.
• Point out the analogy between velocity and acceleration. Just as velocity describes how quickly an object’s position changes over time, acceleration describes how quickly an object’s velocity changes over time. Velocity is the slope of a position-time graph, and acceleration is the slope of a velocity-time graph.
• Emphasize that acceleration is a vector quantity. Ask, *What can you tell about an object’s velocity from the direction of an acceleration vector?* (The direction of acceleration indicates the direction of velocity changes.) Make sure students understand that the direction of velocity is not always the same as the direction of acceleration.
• Draw students’ attention to Tutorial 1: Calculating Acceleration on page 23 of the Student Book.
• Work through Sample Problem 1 with the class. The first part of the problem is a straightforward application of the acceleration equation. The second part of the problem compares the acceleration for different time intervals. Emphasize the conclusion: If the time interval of a specific velocity change is shorter, a more rapid acceleration occurs.
• Work through Sample Problems 2 and 3 with the class. Sample Problem 3 demonstrates how to solve a problem when the velocity vectors are in different directions. Use a vector diagram to represent the problem. Caution students to use the correct directions for the vectors. Unlike adding position vectors to find displacement, velocity vectors are subtracted to find acceleration. The vector for \( \mathbf{v}_1 \) should be 10 units in one direction. The \( \mathbf{v}_1 \) vector points in the opposite direction. However, because it is subtracted, you equivalently add a vector for 8 units in the same direction as the \( \mathbf{v}_1 \) vector.
• Allow time for students to work through the Practice Problems in class. Stress the importance of using the correct number of significant digits in answers.
• Draw students’ attention to Tutorial 2: Solving the Acceleration Equation for Other Variables on page 25 of the Student Book.
• Work through Sample Problem 1 with the class. Emphasize to students that they must solve the two-step equation for the desired variable before substituting known quantities for the variables.
• Have students work through the practice problems. For Sample Problem 2, students may need help rearranging the acceleration equation to solve for the initial velocity variable.
• Draw students’ attention to Tutorial 3: Determining Displacement from a Velocity-Time Graph on page 25 of the Student Book.
• Work through the sample problems with students. Ask, *Why did the second sample problem require finding two areas?* (The total area under the graph was the sum of the rectangular area and the triangular area.)
• Allow time for students to solve the Practice Problems in class. Explain that for these problems they will find the displacement only during part of an object’s motion.
• Have students complete Mini Investigation: Motion Simulations.

MINI INVESTIGATION: MOTION SIMULATIONS

Skills: Predicting, Performing, Observing, Analyzing, Communicating

Purpose: Students will use a computer simulation for four different motion scenarios and then analyze the scenarios by graphing.

Equipment and Materials (per group): computer access; graphing paper

Notes
• Have students work with a partner for this investigation.
• Demonstrate how to access the link to the Nelson website and go to the simulation.
• Allow time for students to familiarize themselves with the simulation before starting. If they have difficulty completing the activity, guide them in a review of the graphs and tutorials they have studied in this section.
• Have students read the first two paragraphs of “Instantaneous Velocity and Average Velocity.” Ask, *How are instantaneous velocity and average velocity different?* (Instantaneous velocity is measured at a specific moment. Average velocity is measured over a certain time interval.)
• Draw students’ attention to Tutorial 4: Determining Instantaneous and Average Velocity on page 27 of the Student Book.
• If possible, provide students with plane mirrors to practise drawing tangents to the curves of position-time graphs.
• Work through the Sample Problems with the class. For Sample Problem 1, explain that a plane mirror can be used to determine the original tangent. This line has been extended to the point (4.0, 12) for convenience. However, other points on the line could equivalently be used.
• Work through Sample Problem 2 with the class. Then review by asking, *How can you determine instantaneous and average velocity from a velocity-time graph?*
Instantaneous velocity at any point is the slope of the tangent line at that point. Average velocity between any two points is the difference in the instantaneous velocity divided by the time interval.

- Allow time for students to work through the Practice Problems in class.

**EXTEND AND ASSESS**

- To provide students with more practice determining average acceleration and displacement from a velocity-time graph, distribute BLM 1.3-1 Analyzing a Velocity-Time Graph, and have students complete it.
- Write these sentences on the board for students to complete: The slope of a velocity-time graph gives the _______ of the object. The area under a velocity-time graph gives the _______ of the object. (acceleration; displacement)
- For additional practice, have students determine the instantaneous velocity at points not yet used on the graph in Figure 6 and determine the average velocity between various points not yet used on the graph in Figure 7.
- Have students complete the Questions on page 30 of the Student Book.

**DIFFERENTIATED INSTRUCTION**

- To support visual learners, post large versions of the different velocity-time graphs in the classroom. Auditory learners should be encouraged to describe the shape of the graphs in their own words. Kinesthetic learners should be encouraged to demonstrate the type of acceleration displayed on each graph.

**ENGLISH LANGUAGE LEARNERS**

- Have English language learners work with partners to complete the Practice Problems. Review the answers to the problems with the class, and write each calculation required to arrive at the solution.

**ASSESSMENT RESOURCES**

Assessment Rubric 4: Application
Assessment Summary 4: Application

**PROGRAM RESOURCES**

Skills Handbook A6 Math Skills
Physics 11 ExamView® Test Bank
Physics 11 Online Teaching Centre
Physics 11 website
www.nelson.com/onseniorscience/physics11u

**RELATED RESOURCES**


**EVIDENCE OF LEARNING**

Look for evidence that students can
- determine the velocity of an object from the area under an acceleration-time graph
- construct one type of motion graph by analyzing another type of motion graph

**SCIENCE BACKGROUND**

- Position-time graphs sometimes show abrupt changes between a rising line, a horizontal line, and a falling line. When describing real motion, the changes are rarely abrupt. Objects always experience some period of slowing down or speeding up.

**POSSIBLE MISCONCEPTIONS**

**Identify:** Students might think a fast speed implies a high acceleration.

**Clarify:** An object’s speed does not determine its acceleration. Acceleration depends only on the change in velocity, not on either speed or velocity alone. It is possible for an object with a low speed to have a high acceleration, and it is possible for an object with a high speed to have a low acceleration.

**Ask What They Think Now:** At the end of this discussion, ask, How is it possible for a bicyclist to have a greater acceleration than a fast-moving car? (The bicycle might have increased its speed quickly, and the fast-moving car might have increased its speed slowly.)

**TEACHING NOTES**

**ENGAGE**

- On the board, draw three simple graphs side-by-side—one with an increasing diagonal line, one with a decreasing diagonal line, and the third with a horizontal line. Point to the graph with the increasing line and ask, If this were a position-time graph, what would it tell you about the position? (The position is steadily increasing.)

What would a velocity-time graph for the motion look like? (a horizontal line in the first quadrant) Ask
analogous questions for the other two graphs. Explain to students that position-time graphs and velocity-time graphs are related. In this section, they will learn to relate acceleration-time graphs as well.

EXPLORE AND EXPLAIN
• Have students read the introductory paragraphs and look at the cheetah in Figure 1. Ask, What do you think a velocity-time graph of the cheetah’s motion would look like if the cat accelerated at a constant rate? (a steep diagonal line) How would this be different for an animal that accelerated at a slower constant rate? (The line would not be as steep.)
• After students read “Acceleration-Time Graphs” ask, What would the graph in Figure 2 look like if the cheetah accelerated at a lower rate? (The line would be lower on the graph.) What would it look like if the cheetah slowed down at the same rate? (It would be a horizontal line below the horizontal axis.)
• On the board, draw an acceleration-time graph similar to the one in Figure 2. Show various uniform acceleration lines, and have students calculate the change in velocity for each.
• Have students study the graphs in Figure 3. Ask, What is the meaning of the arrows labeled “area” and “slope” between the graphs? (The slope of a position-time graph describes the velocity-time graph, and the area under the velocity-time graph represents the change in position shown on the position-time graph. The slope of a velocity-time graph describes the acceleration-time graph, and the area under the acceleration-time graph represents the change in velocity shown on the velocity-time graph.)
• Draw students’ attention to Tutorial 1: Creating One Type of Motion Graph from Another on page 33 of the Student Book.

EXTEND AND ASSESS
• Allow time for students to solve the Practice Problems in class, and then have them create their own practice problems and exchange them with a partner.
• Have students complete Investigation 1.4.1. Applicable teaching notes can be found on page 27 of this resource.
• Have students complete Investigation 1.4.2. Applicable teaching notes can be found on page 28 of this resource.
• Have students complete the Questions on page 35 of the Student Book.

DIFFERENTIATED INSTRUCTION
• Kinesthetic learners will benefit from a matching exercise in which they must group distance-time graphs with their corresponding velocity-time graphs and acceleration-time graphs. Auditory learners should explain the relationship between the three graphs. Visual learners may prefer to draw possible versions of two graphs given the third.

ENGLISH LANGUAGE LEARNERS
• To make it easier for students to interpret graphs, post a line graph that has all of the components such as the x- and y-axes, slope, and intercepts labelled. Students can use the graph for reference if they struggle with the vocabulary used in the Tutorials and Practice Problems.
EVIDENCE OF LEARNING
Look for evidence that students can
• explain the five key equations of uniform accelerated motion
• correctly choose and apply an equation of motion when solving a uniform accelerated motion problem

SCIENCE BACKGROUND
• Different notations are sometimes used for the variables in the equations for motion. The initial velocity, \(v_i\), may also be written as the original velocity, \(v_0\), or as the first velocity, \(v_1\). The final velocity may be written as the second velocity, \(v_f\), so that the change in velocity is \(\Delta v = v_f - v_i\). In addition, the displacement \(\Delta d\) may instead be written as \(\Delta x\), where \(\Delta x = x_f - x_i\). The average acceleration, \(a_{av}\), is often simply written as acceleration, \(a\), even though average acceleration is implied. If the motion is assumed to start at the origin of a coordinate system, with \(d_i = 0\) m and \(t_i = 0\) s, then \(\Delta d\) may be simplified to \(d\) and \(\Delta t\) may be simplified to \(t\).
• An alternative way to explain the displacement equation (labeled Equation 1 in this section) is to consider the area of a trapezoid:

![Trapezoid Diagram]

On a velocity-time graph, the sides of the trapezoid are \(v_f\) and \(v_i\), and the base is \(\Delta t\). Because the area under a velocity-time graph is displacement, the equation follows:

\[
\Delta d = \frac{1}{2} (v_f + v_i) \Delta t
\]

TEACHING NOTES
ENGAGE
• Tell students to imagine that they are riding in a car, and the car begins to accelerate smoothly. The uniform acceleration causes them to feel a gentle push backward. Then tell them to imagine riding in a car in stop-and-go traffic. They speed up and slow down. Explain that this is an example of non-uniform acceleration. Point out that the equations of motion they will use in this section only apply if the acceleration is uniform.

EXPLORE AND EXPLAIN
• Work through the derivation for Equation 1 using the graph in Figure 1 as an example of the area of a triangle and the area of a rectangle. Ask, How would this equation and the derivation change if the initial velocity were zero? (If \(v_i\) were zero, the equation would be

\[
\Delta d = \frac{1}{2} \Delta v \Delta t
\]

The derivation would include only the area of the triangle.)
• Work through the derivations for Equation 2 and Equation 3. Ask, When would you probably choose to use these equations? (You would use Equation 2 when you do not know the displacement. You would use Equation 3 when you do not know the final velocity.)
• Emphasize to students the importance of being able to use the equations in Table 1. Explain that these are the tools they will have available for solving motion problems.
• Draw students’ attention to Tutorial 1: Using the Five Key Equations of Accelerated Motion on page 38 of the Student Book.
• Work through Sample Problems 1 and 2 with the class. Students might think that the unknown quantity should be the variable in Table 1 that is listed under the heading “Variables not in equation.” Clarify that in order to solve for an unknown quantity, variables for each of the given quantities and the unknown quantity must be present in the equation.
• Point out that the first step in solving each of the Sample Problems is to list the given and required quantities. The second step is to identify the equation that should be used. The third step is to rearrange the equation for the required variable. Finally, students should substitute the given quantities and solve the equation.
• Work through Sample Problem 3, emphasizing the use of the defining equation for acceleration. Tell students that they may also encounter situations in problems when they need to use the defining equation for velocity or displacement. Remind students that they must also calculate the change in velocity.
• Allow class time for students to work through the Practice Problems. In each case, encourage students to use the step-by-step procedures demonstrated in the Sample Problems.

EXTEND AND ASSESS
• Have students complete BLM 1.5-1 Using Equations of Accelerated Motion.
• Have students make flashcards on which they write the variables present in each of the five key motion equations on one side of a card, and the corresponding equation on the other side. Encourage them to work through the flashcards as much as possible so that they can quickly decide which equation to use for each motion problem they solve.
• Have students complete the Questions on page 39 of the Student Book.
DIFFERENTIATED INSTRUCTION
• For each equation discussed in this section, encourage students to describe the graph and the information it conveys in a manner meaningful to them. Visual learners may choose to draw a representative graph and write a description of the information conveyed by both the graph and the equation; auditory learners may prefer to discuss the shape of the graph and its meaning; kinesthetic learners may prefer to physically demonstrate the shape of the graph and its meaning.

ENGLISH LANGUAGE LEARNERS
• Ask students to think of common ways that the word displace is used and compare those meanings to the definition of displacement as it is used in regard to kinetics. For example, medical professionals refer to displaced fractures, and people who have lost their homes are sometimes referred to as displaced.

1.6 Acceleration Near Earth’s Surface

OVERALL EXPECTATIONS: B2; B3

SPECIFIC EXPECTATIONS
Developing Skills of Investigation and Communication:
B2.1; B2.8

Understanding Basic Concepts: B3.3

The full Overall and Specific Expectations are listed on pages 3–5.

ASSESSMENT RESOURCES
Assessment Rubric 1: Knowledge and Understanding
Assessment Summary 1: Knowledge and Understanding

PROGRAM RESOURCES
BLM 1.6-1 Rising and Falling Motion
Skills Handbook A6 Math Skills
Physics 11 ExamView® Test Bank
Physics 11 Online Teaching Centre
Physics 11 website
www.nelson.com/onseniorscience/physics11u

RELATED RESOURCES

EVIDENCE OF LEARNING
Look for evidence that students can
• identify the value of \( g \), the acceleration due to gravity
• describe how air resistance affects the acceleration of objects
• explain terminal velocity and how it applies to a falling object

SCIENCE BACKGROUND
• The value of Earth’s gravitational acceleration, \( g \), can be calculated from the equation for universal gravitation between any two objects with masses \( m_1 \) and \( m_2 \), which are separated by a distance \( r \) between their centres of mass:

\[
F_{\text{grav}} = \frac{G m_1 m_2}{r^2}
\]

The value of the universal gravitation constant \( G \) has been experimentally found to be equal to \( 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2 \). Substituting Earth’s mass, \( 6.0 \times 10^{24} \text{ kg} \), and average radius, \( 6.4 \times 10^6 \text{ m} \), gives:

\[
F_{\text{grav}} = \left(9.8 \text{ m/s}^2\right) m_{\text{object}}
\]

(Note that the derivation uses the conversion 1 N = 1 kg·m/s².)

• It is important to keep in mind that air resistance is not always upward, as it is for a parachutist. Transfer trucks, for example, often have large deflectors and rounded corners to help streamline their design against the horizontal onrush of air. Air resistance against the motion of parachutists, automobiles, or airplanes is called drag. Airplanes also face other wind effects, such as lift, in which air pushes upward on the plane.

TEACHING NOTES
ENGAGE
• Have students imagine a basketball player making a jump shot, or show a few minutes of a video of a basketball game. Ask, Why does it appear that the player hangs in the air? (She accelerates to jump, then her motion slows, stops, and accelerates again on the way down.) Tell them that this section will explain how that happens.

EXPLORE AND EXPLAIN
• Students may think the Earth’s gravitational acceleration is exactly 9.8 m/s² everywhere on Earth, or they may think that it varies significantly from this value. Explain that the acceleration due to gravity depends on a person or object’s distance from Earth’s centre. Even the heights of the tallest mountains are small compared to Earth’s radius. As a result, the variations in \( g \) are small anywhere near Earth’s surface.

• After students have read “Acceleration Due to Gravity,” explain that gravity does not depend on an object’s mass. To emphasize this point, have students drop a book and a piece of paper side-by-side. The paper will fall slower than the book. Next, have them place the paper on the book and drop the book again. Without the effect of air resistance, the paper and book fall at the same rate. The low mass of the paper does not affect acceleration.
• Read aloud the heading “Uniform Vertical Acceleration.”
  Ask, Is Earth’s gravitational acceleration uniform?
  (Close to the surface it varies slightly, but not enough to
  affect the equations of motion.) Explain that even on the
  highest mountain, the value of g is 9.8 m/s².
• Draw students’ attention to Tutorial 1 on page 40 of the
  Student Book. Work through the Sample Problems with
  the class.
• When working Sample Problem 1, point out that the
  directions up and to the right are typically chosen as
  positive, similar to a coordinate grid. Emphasize that
  choosing direction consistently minimizes confusion.
• Some students may need help solving problems involving
  square roots. Remind them that they cannot take the
  square root of a negative value. If they face this in a
  problem, they have made a mistake in setting up the
  directions of the variables.
• For Sample Problem 2, make sure it is clear to students
  that, from the given information, the velocity must be
  downward. The magnitude of the resultant vector is 14
  m/s. If accounting for direction, it would be assigned a
  negative value.
• Allow time for students to work the Practice Problems in
  class. Make sure students start by listing the given
  variables and the required variable. In both cases, the
  acceleration is 9.8 m/s². Encourage students to designate
  upward acceleration as positive when they choose the
  sign of g.
• Draw students’ attention to Tutorial 2 on page 41 of the
  Student Book. Have students study the drawing and
  variables in Figure 2. Ask, What is the ball’s velocity just
  at the top of its trajectory? (zero) Is this always true for
  an object thrown straight upward? (yes) What is its
  acceleration on the way up? (–9.8 m/s²) What is its
  acceleration at the top of its trajectory? (–9.8 m/s²) What
  is its acceleration on the way down?
  (–9.8 m/s²) Explain that if the initial velocity is v₀, then
  its velocity on the way down at that same height is –v₀.
• Work through Sample Problems 1 and 2 with the class. Point
  out that both consider only the rising motion of the
  ball, but information could also be inferred about the
  falling motion of the ball. For example, ask, How much
time would elapse between the throw and the catch if the
person caught the falling ball at the same height that it
was launched? (0.62 s) What would its velocity be at this
point? (~3.0 m/s)
• Allow time for students to work Practice Problems 1 and
  2 in class. For Practice Problem 2, the motion is
downward. Because there is an initial non-zero velocity, it
is solved just like a problem with an object thrown
upward.
• After students read “Free Fall and Terminal Velocity,”
point out that the value of terminal velocity depends on
various factors, such as the weight of the falling object.
Tell students that they will study terminal velocity in
more detail later in the text.

EXTEND AND ASSESS
• Distribute BLM 1.6-1 Rising and Falling Motion, and
  have students complete it.
• Divide the class into pairs. Have each pair write one
  problem that involves an object falling straight down and
  one for an object thrown upward. Instruct students to
  trade problems with another group and solve them.
• Have students complete the Questions on page 43 of the
  Student Book.

DIFFERENTIATED INSTRUCTION
• To assist visual and kinesthetic learners in understanding
  the situations presented in the problems, invite them to
  recreate each scenario described. Auditory learners may
  find it helpful to orally summarize the problems in their
  own words before begin to work on the solutions.

ENGLISH LANGUAGE LEARNERS
• After English language learners have completed the
  problems in this section, encourage them to reread the
  section. Have them choose one of the problems that they
  found most challenging, and point out which sections of
  the text contain information useful in finding the solution.

1.7 Explore an Issue in Vehicle Safety

OVERALL EXPECTATIONS: A1; B1; B2

SPECIFIC EXPECTATIONS
Scientific Investigation Skills: A1.3; A1.7; A1.9; A1.10; A1.11
Relating Science to Technology, Society, and the Environment: B1.1; B1.2
Developing Skills of Investigation and Communication: B2.1

The full Overall and Specific Expectations are listed on
pages 3–5.

SKILLS
  Researching Analyzing the Issue
  Identifying Alternatives

ASSESSMENT RESOURCES
  Assessment Rubric 9: Explore an Issue
  Assessment Summary 9: Explore an Issue
  Self-Assessment Checklist 5: Explore an Issue
PROGRAM RESOURCES
BLM 0.0-4 Concept Map
Skills Handbook A5 Exploring Issues and Applications
Physics 11 ExamView® Test Bank
Physics 11 Online Teaching Centre
Physics 11 website
www.nelson.com/onseniorscience/physics11u

RELATED RESOURCES

EVIDENCE OF LEARNING
Look for evidence that students can
• research and analyze an issue that affects society
• identify various solutions to a controversial issue

SCIENCE BACKGROUND
• Another name for a speed limiter is a governor. These
devices have been used for many years to limit the speed
of vehicles. For example, some companies limit the speed
of vehicles used by their drivers to reduce possibility of
accidents. Some private vehicles contain speed limiters
that allow owners to choose a maximum speed for
themselves. Starting in January of 2009, large trucks in
Ontario were required to use speed limiters that restricted
their speed to a maximum of 105 km/h.

TEACHING NOTES
THE ISSUE
• Have students read about speed limiters and the proposal
to install them in vehicles. Allow class time for students
to give their initial ideas about this proposal. Point out
that many innovations have improved safety in modern
life, but are only effective if people use them.

GOAL
• Divide the class into small groups. Have each group
discuss the goals and positions different people might
have regarding the proposal.

ROLE
• Instruct groups to discuss how a member of the provincial
student council association representing young drivers
might consider the issue. Possibilities include gathering
information on the opinions held by other students,
compiling relevant data, and conducting other kinds of
research on the topic.

AUDIENCE
• Remind students that arguments in any debate should
engage the intended audience. Suggest that they explain
any scientific arguments in a manner all members of the
audience will understand.

RESEARCH
• As students begin their research, remind them that an
important part of debate is to research arguments against
your position so that you can defend against them.

IDENTIFY SOLUTIONS
• Provide groups with a copy of BLM 0.0-4 Concept Map to
help them organize their ideas for their proposed
solutions.

MAKE A DECISION
• In their groups, have students decide which solution they
think is best.

COMMUNICATE
• Encourage students to make their presentations as
appealing and as convincing as possible. Suggest that
they include proven facts that support their position.
• Allow time for groups to show their presentations to the
class. Conduct a class debate about the possible solutions.

PLAN FOR ACTION
• Emphasize to students that speaking out about important
issues is a powerful way to influence society, but it
should always be done in a respectful and thoughtful
manner.

DIFFERENTIATED INSTRUCTION
• Student could be encouraged to work in multimodal
groups. Visual students could be responsible for
developing the visual component of the presentation such
as charts, graphs, and pictures; auditory students could
work on the ‘script’; kinesthetic learners could work on
the computer presentation and present their information to
the class.

ENGLISH LANGUAGE LEARNERS
• Encourage English language learners to gather
information from their families and friends about their
opinions on the topic. Suggest that they create a short
presentation in their native language that will explain the
controversy to other speakers of their native language.

1 Investigations

1.2.1 Observational Study: Watch Your Speed

OVERALL EXPECTATIONS: A1; B2; B3

SPECIFIC EXPECTATIONS
Scientific Investigation Skills: A1.5; A1.8, A1.13
Developing Skills of Investigation and Communication:
B2.1; B2.4

NEL Motion in a Straight Line 25
Understanding Basic Concepts: B3.1

The full Overall and Specific Expectations are listed on pages 3–5.

SKILLS
Performing  Evaluating
Observing  Communicating
Analyzing

EQUIPMENT AND MATERIALS
per group:
• 25 m–50 m tape measure
• stake or other marker
• stopwatch

ASSESSMENT RESOURCES
Assessment Rubric 7: Observational Study
Assessment Summary 7: Observational Study
Self-Assessment Checklist 3: Observational Study

PROGRAM RESOURCES
Skills Handbook A2 Scientific Inquiry
Physics 11 ExamView® Test Bank
Physics 11 Online Teaching Centre
Physics 11 website
www.nelson.com/onseniorscience/physics11u

RELATED RESOURCES

EVIDENCE OF LEARNING
Look for evidence that students can
• follow safety precautions when making measurements in a real-life situation
• make distance and time measurements, using standard equipment
• calculate average speed from distance and time data

SCIENCE BACKGROUND
• For measurements in this investigation, the average speed equation \( \bar{v} = \frac{\Delta d}{\Delta t} \) could equivalently be written as \( \bar{v} = \frac{1}{2}(v_i + v_f) \), where \( v_i \) is the velocity of the car just as it enters the measurement area and \( v_f \) is its velocity just at the moment it leaves the measurement area. However, using this version of the equation requires that the initial and final velocities of the car be known. The equation is interesting because it highlights the fact that the average speed only depends on the beginning and ending speeds; the speed of the car could increase or decrease many times during the measurement period.
• In order to ensure safety of students, speed zones are established around schools in which the posted maximum may be much lower than that of surrounding roads. A typical speed zone maximum around a school is 30 km/h. If the measurement distance for this investigation is 50 m, the time for a car to travel through the area at the maximum speed would be 6 s.

TEACHING NOTES

STUDENT SAFETY
• Instruct students to choose a safe location for the investigation.
• Caution them to stand a safe distance from the curb for the study. Stress the importance of remaining aware of their surroundings while making observations.
• Have students work in small groups for this investigation. Suggest that two or three students watch the starting and ending points and make measurements, one student record the data, and one student watch the surroundings for any unsafe conditions that might arise.
• Encourage students to make a data table for their measurements before they start.
• Suggest taking a clipboard or other hard surface on which to write while making measurements.

PURPOSE
• Students will measure the time required for cars to travel a certain distance. They will use this data to calculate average speed.

EQUIPMENT AND MATERIALS
• If long tape measures are not available, have students measure 25 m lengths of rope with a metre stick before the activity begins.

PROCEDURE
• Remind students of the importance of measuring the time carefully. Suggest that groups have students positioned at the starting and ending points to call out “Start!” and “Stop!” for the person observing the stopwatch.
• Provide guidance as groups choose locations and times for their investigations. They should consider whether 50 vehicles would likely pass the location within a reasonable time period.

OBSERVATIONS
• Have students prepare a lab report that includes their data, their average speed calculations, and a summary paragraph.

DIFFERENTIATED INSTRUCTION
• Encourage students to record the investigation results in a manner that makes the most sense to them. Visual learners may prefer sketches and labels, while others might choose tables or other strategies.

ENGLISH LANGUAGE LEARNERS
• Remind English language learners to refer to their notes and vocabulary lists when answering the questions and
writing lab reports. Allow them to work in pairs or small
groups, and encourage them to discuss their responses
with peers before writing them down.

1.4.1 Observational Study: Uniform Velocity

OVERALL EXPECTATIONS: A1; B2; B3

SPECIFIC EXPECTATIONS

Scientific Investigation Skills: A1.5; A1.6; A1.8, A1.10,
A1.13
Developing Skills of Investigation and Communication:
B2.1; B2.4
Understanding Basic Concepts: B3.2

The full Overall and Specific Expectations are listed on
pages 3–5.

SKILLS
Researching Analyzing
Predicting Evaluating
Performing Communicating
Observing

EQUIPMENT AND MATERIALS
per group:
• motion sensor
• computer or computer interface
• motorized toy truck
• metre stick
• data storage device such as a USB drive (memory stick)
• graph paper (optional)

ASSESSMENT RESOURCES
Assessment Rubric 7: Observational Study
Assessment Summary 7: Observational Study
Self-Assessment Checklist 3: Observational Study

PROGRAM RESOURCES
Skills Handbook A2 Scientific Inquiry
Physics 11 ExamView® Test Bank
Physics 11 Online Teaching Centre
Physics 11 website
www.nelson.com/onseniorscience/physics11u

RELATED RESOURCES
Epstein, Lewis Carroll. Thinking Physics: Understandable

EVIDENCE OF LEARNING
Look for evidence that students can
• use a motion sensor to take motion data
• generate graphs from motion sensor data
• analyze graphs to learn about the motion of an object

SCIENCE BACKGROUND
• A motion sensor is an ultrasonic transceiver. As the name
implies, a transceiver is an electronic device that includes
both a transmitter and a receiver. There are different types
of transceivers. However, in the case of a motion sensor,
the signal transmitted is the ultrasonic signal. In order to
calculate position–time data, velocity–time data, and
acceleration–time data, the motion sensor must include
the transmitter that sends out the signal and the receiver
that detects the reflected signal.
• An ultrasonic signal is a high-frequency sound wave.
Humans can hear sounds in the range of about 20 Hz to
20 kHz, where a hertz (Hz) is one wave per second.
Sounds with lower frequencies are called infrasound, and
sounds with higher frequencies are called ultrasound. A
typical motion sensor might use a sound wave of about 50
kHz, which is a frequency too high for humans to hear.
The sensor sends out a sound pulse and measures the time
interval, \( \Delta t \), until the reflected signal (echo) is detected.
Using the speed of sound in air (about 346 m/s) and the
average speed equation, the sensor calculates the distance
to the object.

TEACHING NOTES
• Have students work in small groups for the investigation.

PURPOSE
• Students will use a motion sensor to analyze the motion
of a toy truck as it moves along a horizontal path.

EQUIPMENT AND MATERIALS
• Check to be sure the motion sensor and computer
interface work properly.
• Test the motorized vehicle or any substitute vehicles to be
sure clear data can be obtained with the motion sensor.

PROCEDURE
• Allow time for students to become familiar with the
motion sensor and computer interface. Advise them to
make several trial runs before recording data.
• Students may need help generating and analyzing their
graphs. Some students may need to review the graphs
throughout this chapter.

OBSERVATIONS
• Allow class time for groups to present and explain their
graphs to the class.

DIFFERENTIATED INSTRUCTION
• It may be useful for students with different learning styles
to work together in groups. Auditory learners can explain
the process and phrase the answers; visual learners can
record the information in an appropriate chart; kinesthetic
learners can work with the manipulatives.
ENGLISH LANGUAGE LEARNERS
• Check in with English language learners to ensure they understand the concepts being addressed as well as the new terms and problem-solving techniques. During the investigation, have them orally summarize the description of how the motion sensor works, the design of the investigation, and their expected results.

1.4.2 Observational Study: Motion Down a Ramp

OVERALL EXPECTATIONS: A1; B2; B3

SPECIFIC EXPECTATIONS
Developing Skills of Investigation and Communication: B2.1; B2.2; B2.4
Understanding Basic Concepts: B3.2

The full Overall and Specific Expectations are listed on pages 3–5.

SKILLS
Performing Evaluating
Observing Communicating
Analyzing

EQUIPMENT AND MATERIALS
per group:
• motion sensor
• computer or computer interface
• data storage device, such as a USB drive (memory stick)
• PVC pipe
• ramp, 1.5 m or longer
• textbooks or wood blocks
• metre stick
• masking tape
• graph paper (optional)

ASSESSMENT RESOURCES
Assessment Rubric 7: Observational Study
Assessment Summary 7: Observational Study
Self-Assessment Checklist 3: Observational Study

PROGRAM RESOURCES
Skills Handbook A2 Scientific Inquiry
Physics 11 ExamView® Test Bank
Physics 11 Online Teaching Centre
Physics 11 website
www.nelson.com/onseniorscience/physics11u

RELATED RESOURCES

EVIDENCE OF LEARNING
Look for evidence that students can
• use a motion detector to gather data
• analyze graphs from data collected by a motion detector

SCIENCE BACKGROUND
• When an object moves down a ramp, the force of gravity is still responsible for the object’s downward motion, but the angle of the ramp affects the motion. The component of gravity that pulls the object down the ramp is \( mgsin\theta \), where \( m \) is the mass of the object and \( \theta \) is the angle the ramp makes with the horizontal.

• The frictional force that an object experiences as it rolls down a ramp is much less than it would be if the object were sliding down the ramp. The frictional force acts against the force of gravity pulling the object down the ramp. In general, the frictional force resisting an object’s motion is given by this equation: \( F_{\text{friction}} = \mu N \), where \( \mu \) is the coefficient of friction and \( N \) is the normal force. For an object moving down a ramp, \( N = mgsin\theta \), where \( m \) is the mass of the object and \( \theta \) is the angle of the ramp. The coefficient of friction, \( \mu \), is much lower for a rolling object than for a pulled object, which means the frictional resistance of the object is minimal. In this investigation, this effect means the rolling PVC pipe experiences almost uniform acceleration due to gravity.

TEACHING NOTES

PURPOSE
• Students use a motion sensor to collect motion data for a pipe rolling down a ramp. They then analyze the graphs from this data to learn about the motion of the pipe.

EQUIPMENT AND MATERIALS
• Decide ahead of time how students can set up their ramps. A sheet of plywood positioned against steps or an existing access ramp can be used. Each group can take turns using a ramp.

PROCEDURE
• Instruct students to work in small groups for this investigation.
• Have students study the setup shown in Figure 1.
• Suggest that students test their setup with the motion sensor several times before making the actual measurements.

OBSERVATIONS
• Have students prepare a lab report that includes their data, graphs, and a description of their observations and
analysis. Allow time for students to present their data to the class.

DIFFERENTIATED INSTRUCTION
• Make sure students are connecting the motion of the pipe to the graph generated by the computer software. Lead a class discussion during which students describe this motion and its graphic representation in as many different ways as possible. Auditory learners may prefer oral descriptions, while visual and other learners may draw diagrams on the board or act out the investigation with the pipe or other models.

ENGLISH LANGUAGE LEARNERS
• Suggest that English language learners discuss the investigation with family members, and think about other situations in which the concepts illustrated might be applied. Have them create a list of events that show constant velocity, uniform acceleration, and non-uniform acceleration.

ASSESSMENT RESOURCES
Assessment Rubric 1: Knowledge and Understanding
Assessment Rubric 2: Thinking and Investigation
Assessment Summary 1: Knowledge and Understanding
Assessment Summary 2: Thinking and Investigation

PROGRAM RESOURCES
BLM 1.Q Chapter 1 Quiz
Skills Handbook A7 Choosing Appropriate Career Pathways
Physics 11 ExamView® Test Bank
Physics 11 Online Teaching Centre
Physics 11 website
www.nelson.com/onseniorscience/physics11u

RELATED RESOURCES

SUMMARY QUESTIONS
• Ask one or two questions that will prompt students’ recall of each Key Concept. Have students explain and support their responses.
  1. How is the distance an object moves along a path related to its position? (As an object moves from one position to another, the distance it moves is the total length of the path along which it moves between those positions.) How is displacement different from distance? (Displacement is the length of a straight path between two positions. Distance is the length of the actual path of motion between the positions.)
  2. How is speed different from velocity? (Velocity has a direction associated with it. Speed does not.) How is acceleration related to velocity? (Acceleration is the change in velocity over a certain time interval.)
  3. What is an example of a vector quantity? (Sample answer: velocity) What is an example of a scalar quantity? (Sample answer: speed)
  4. If you want to describe the displacement of an object moving along a straight path, when should you add or subtract vectors that describe the motion? (You should add vectors if two displacements are in the same direction. You should subtract vectors if one displacement is in the opposite direction from the other.)
  5. What does a straight line with a positive slope on a position-time graph imply about the motion of an object? (The object has a constant, positive velocity.) What quantity is determined by the area under a velocity-time graph? (the acceleration of the object whose motion is described by the velocity-time graph)
  6. If a person is walking at a velocity 2 m/s [E] along the length of a boat moving at a velocity of 12 m/s [E] relative to the shore, what is the person’s velocity relative to the shore? (14 m/s [E])
  7. What is the value of the acceleration due to gravity close to the surface of Earth? (9.8 m/s²) How does this acceleration affect the motion of an object in free fall? (The object’s velocity increases at a constant rate as the object falls.)
  8. What are the positive and negative impacts that speed limiters might have on teen drivers? (They would force teenagers to drive at a slower speed. They might cause more frustration by drivers, leading to unsafe driving behaviour.)

• Have students look back at the Starting Points questions at the beginning of the chapter. Tell them to consider all of the concepts they have learned in this chapter, and then answer the questions again.
• Return the answers that students wrote for the Starting Points questions before they studied the chapter. Allow time for them to compare their recent answers with the answers they wrote before studying the chapter. Ask students to name some ways that their answers have changed. If their previous answers indicate some misconceptions, discuss why the misconceptions are incorrect.
• Have students complete the questions found in the Chapter Self-Quiz and Chapter Review in the Student Book.
• Have students complete BLM 1.Q Chapter 1 Quiz for an additional review of the material.
CAREER PATHWAYS
• Point out to students that choosing a career so early in their education is not binding. They can change their mind later. However, it is useful to begin thinking about the types of careers that seem interesting. As they continue their education, they might identify other career possibilities that they are drawn to.
• Discuss the types of careers listed in the Student Book. Explain that a biophysicist applies physics concepts to biological systems. A robotics engineer may work in a wide variety of fields, using physics concepts to design and apply robots to perform various tasks.
• Two careers listed in the Student Book that do not necessarily require a Ph.D. are geomatics technician and GIS applications specialist. A geomatics technician might assist with the acquisition and analysis of information related to determining location using various sensors. A geographical information systems (GIS) applications specialist might perform computer modeling to analyze location-related information.

DIFFERENTIATED INSTRUCTION
• Students should be encouraged to summarize the information from this chapter in a format they find useful. Visual learners may prefer a flow chart or other graphic organizer; auditory learners may prefer recording their thoughts or coming up with raps or rhymes to reinforce the concepts. Kinesthetic learners may need to move around the classroom and physically act out the concepts as they review.

ENGLISH LANGUAGE LEARNERS
• After students have completed the investigations and activities in this chapter, encourage English language learners to reread the sections that they found most challenging. Then have them write an outline of the chapter to use as a study guide of its key points.